Laser induced THz spin dynamics in magnetic alloys

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Films of ordered magnetic alloys having uniaxial magnetic anisotropy show a perpendicular magnetic anisotropy, which are of quite importance for recent spintronics applications. On the other hand, a large perpendicular magnetic anisotropy causes very fast spin angular momentum prerecession because the Larmor frequency f is proportional to the magnetic anisotropy field H_k^{eff}. When magnetic films have both a large perpendicular magnetic anisotropy K_u^{eff} and small saturation magnetization M_s, those films can exhibit precession with frequency of f=100-1000 GHz owing to the large $H_k^{eff}=2K_u^{eff}/M_s$. This frequency region overlaps THz wave band, so that it could be expected that new phenomena are emerged from the mutual coupling between various THz excitations and spin dynamics. As a first step of exploring such new field, it is necessary to investigate materials exhibiting THz spin dynamics and its way of manipulation. THz spin precession can be accessed by ultrashort pulse laser, which is also interesting for terahertz wave applications from the practical points of view, such as ultrashort pulse laser driven GaAs THz emitter. While, there are few researches on THz spin dynamics in magnetic alloys, since there are not so much materials having enough large H_k^{eff}.

We, so far, reported various Mn based magnetic alloy films with a large perpendicular magnetic anisotropy of 5-15 Merg/cm^3, such as $D0_{22}$ Mn_3Ga [1], $L1_0$ MnGa [2], C38 MnAlGe [3], and $D0_{22}$ Mn_3Ge [4,5]. Those also have small magnetization of 100-500 emu/cm^3 as well as relatively small Gilbert damping constant. Fig. 1 shows the typical all-optical pump-probe time-resolved Kerr rotation measured in the MnGa epitaxial film using a pulse laser with low laser fluence. After strong ultrafast demagnetization at zero delay time, rapid precession is observed. Similar data were obtained in the other Mn-based alloys films and those frequency values of precession are summarized in Fig. 2 as a function of normal component of applied magnetic field. Precession frequency f linearly increases with increasing field, which was reasonably account as very fast Larmor precession owing to the large H_k^{eff}. The maximum f is 0.55 THz in case of Mn_3Ge epitaxial films. In order to obtain into the insight the physical mechanism behind the laser-induced precession, we investigated laser fluence and field dependence of dynamics and analyzed them using some physical models including thermally induced torque. The dynamics at low fluence region can be well explained by the calculation of one dimensional micromagnetic simulation based on the modified three temperature model taking into account of gradient of electron and lattice temperature (Fig. 1) [6].

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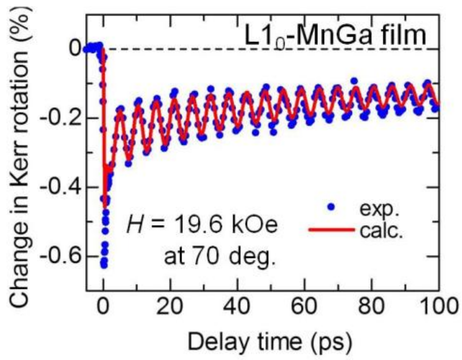

Fig. 1 Laser-induced spin dynamics of MnGa films. Solid curve is fitted to the experimental data.

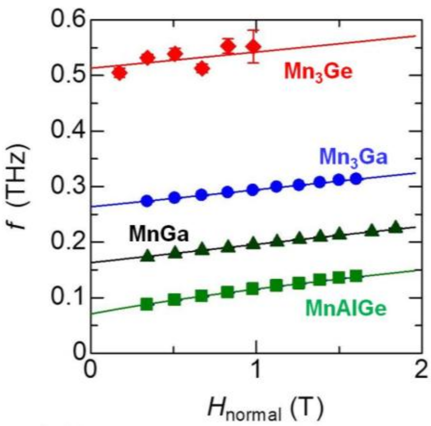

Fig. 2 Laser-induced spin precession frequency as a function of magnetic field for the various Mn-based alloy films. Solid lines are fitted to the data.

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